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Street et al.

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(45) **Date of Patent:** Feb. 6, 2024

(54) **VEHICLE BRAKE PEDAL WITH PEDAL RESISTANCE ASSEMBLY AND FORCE/POSITION SENSOR**

(58) **Field of Classification Search**  
CPC ..... B60T 8/4086; B60T 7/042; B60T 7/06; G01L 5/225  
See application file for complete search history.

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(73) Assignee: **CTS Corporation**, Lisle, IL (US)

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(\* ) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

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(65) **Prior Publication Data**

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(74) *Attorney, Agent, or Firm* — Michael Best & Friedrich LLP

**Related U.S. Application Data**

(60) Division of application No. 16/867,733, filed on May 6, 2020, now Pat. No. 11,597,366, which is a (Continued)

(57) **ABSTRACT**

A brake pedal assembly comprising a pedal and a pedal resistance force member operably coupled to the pedal. A damper pedal resistance force module defines an interior fluid-filled cavity. A shaft extends through the damper module and includes a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force. A spring pedal resistance force module is adapted to generate a spring pedal resistance force. A pedal force sensing module is mounted to the pedal resistance force member. A pedal position sensor is mounted to the pedal resistance force member. A pedal force sensor is mounted to the pedal resistance force member.

(51) **Int. Cl.**

**B60T 8/40** (2006.01)

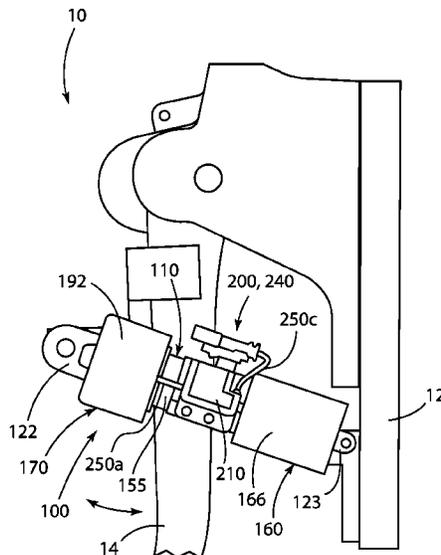
**G01L 5/22** (2006.01)

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**9 Claims, 13 Drawing Sheets**

(52) **U.S. Cl.**

CPC ..... **B60T 8/4086** (2013.01); **B60T 7/042** (2013.01); **B60T 7/06** (2013.01); **G01L 5/225** (2013.01)



**Related U.S. Application Data**

- continuation-in-part of application No. 16/439,822, filed on Jun. 13, 2019, now Pat. No. 10,654,452, which is a continuation of application No. 15/876,772, filed on Jan. 22, 2018, now Pat. No. 10,343,657.
- (60) Provisional application No. 62/992,944, filed on Mar. 21, 2020, provisional application No. 62/845,401, filed on May 9, 2019.

(51) **Int. Cl.**

**B60T 7/06** (2006.01)  
**B60T 7/04** (2006.01)

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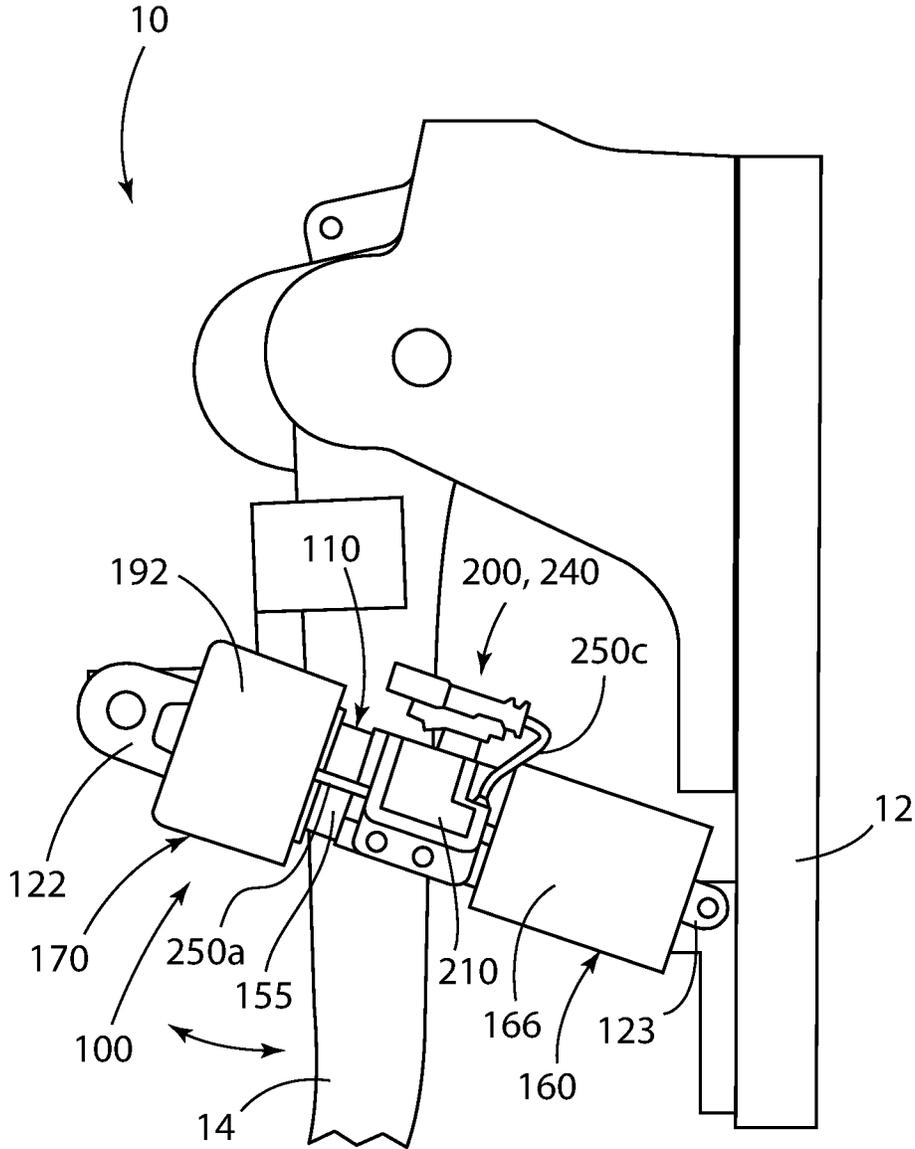


FIG. 1

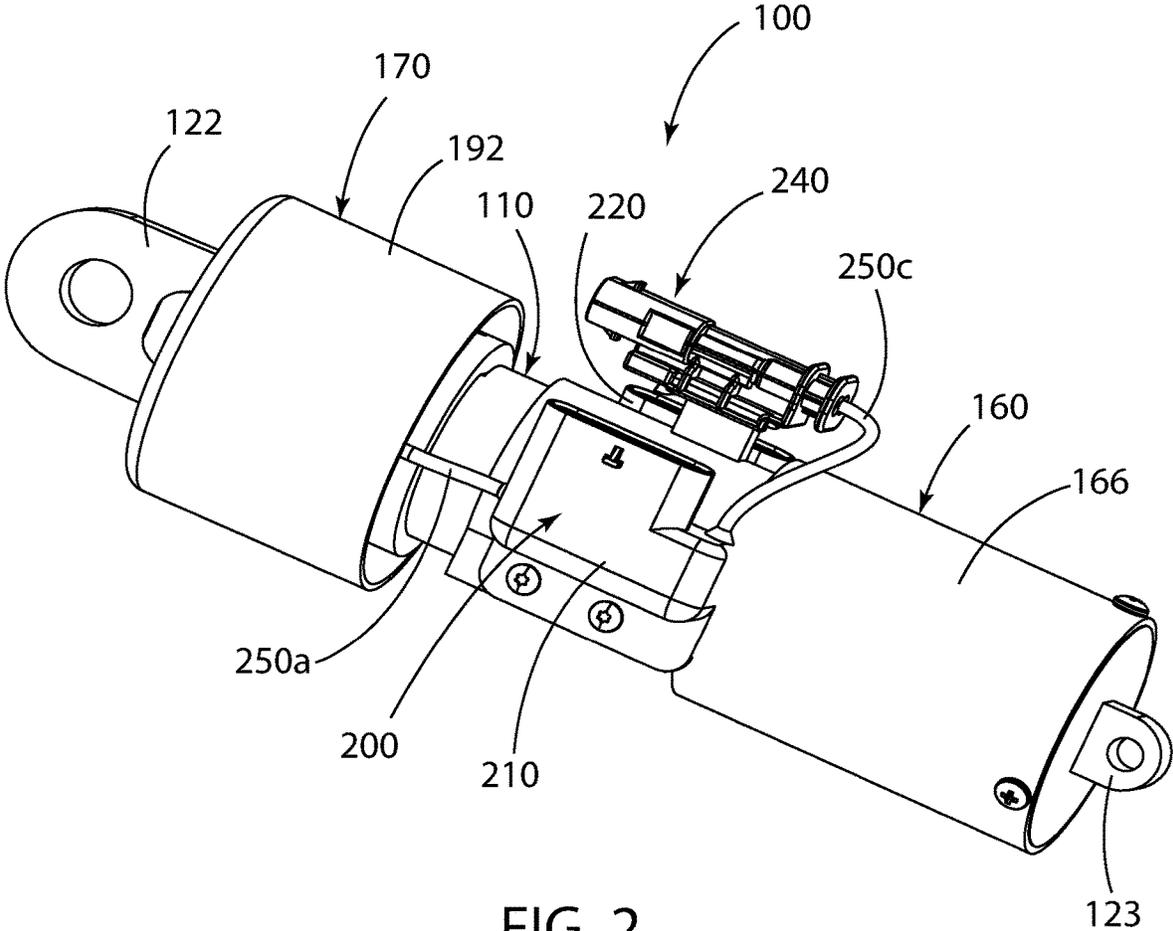


FIG. 2

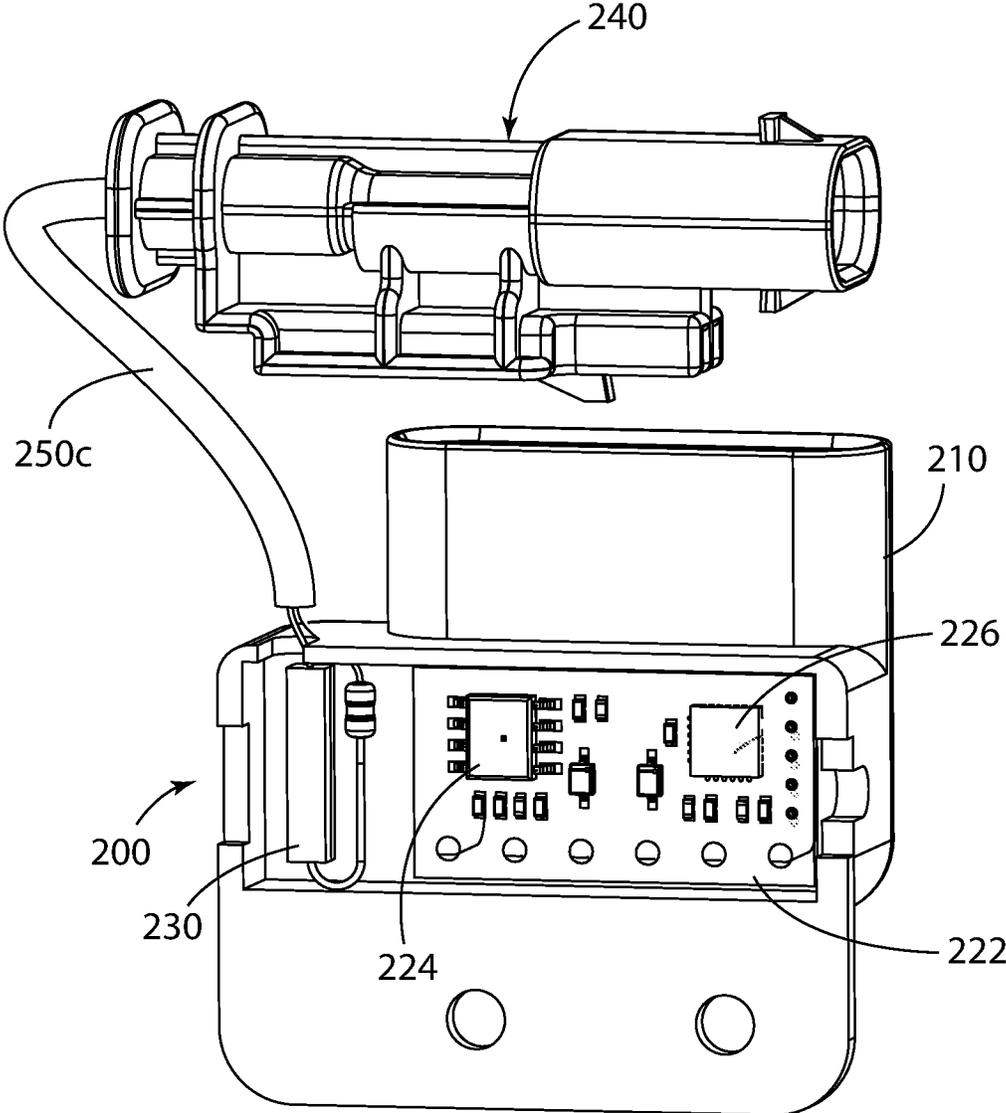


FIG. 3

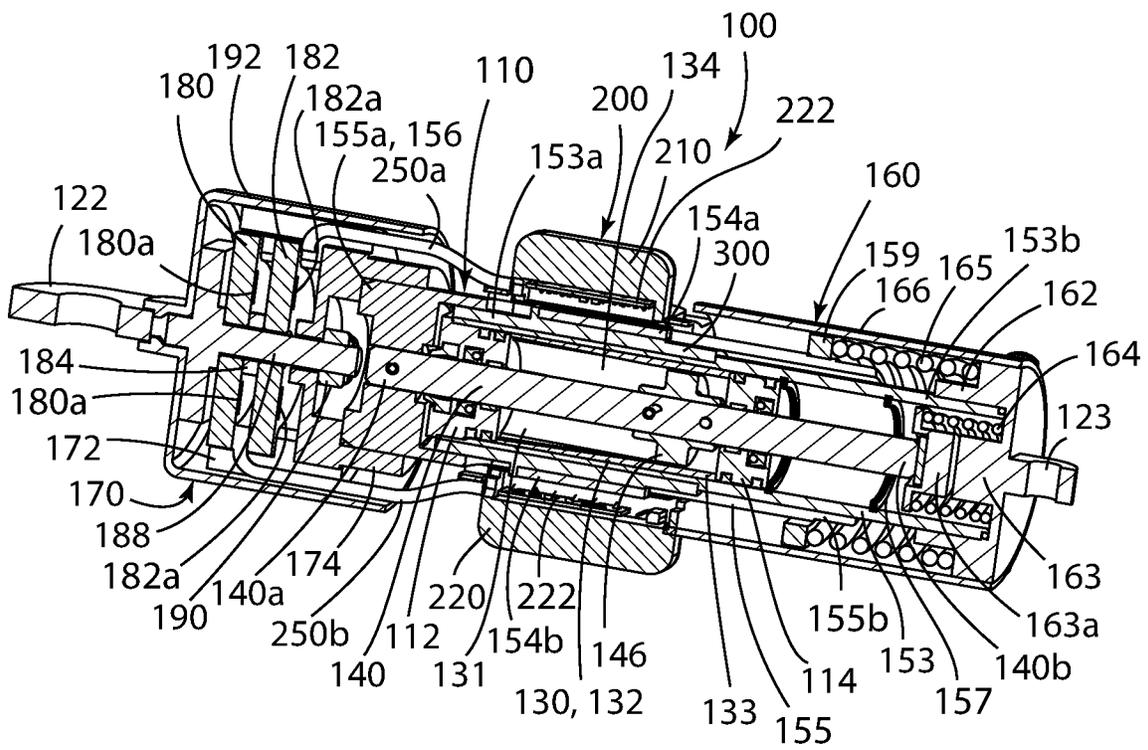


FIG. 4



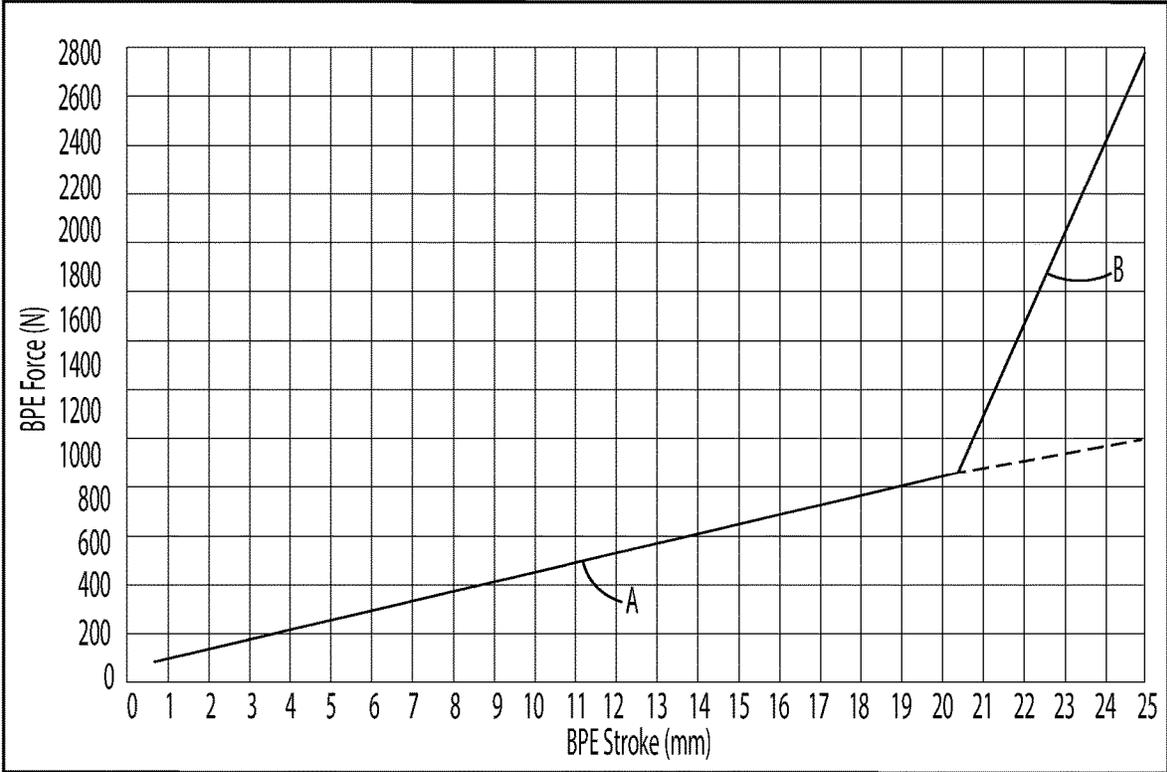


FIG. 8

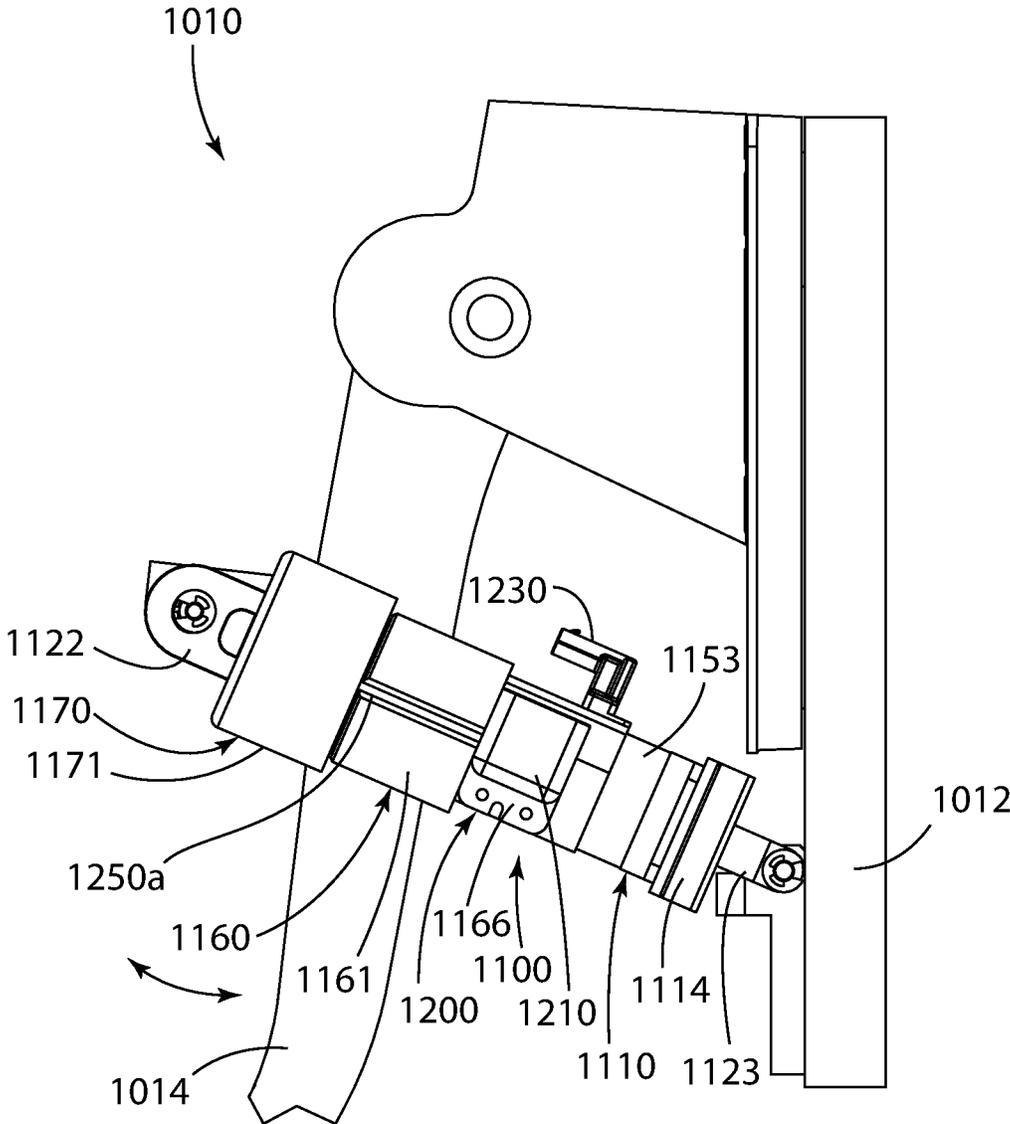


FIG. 9

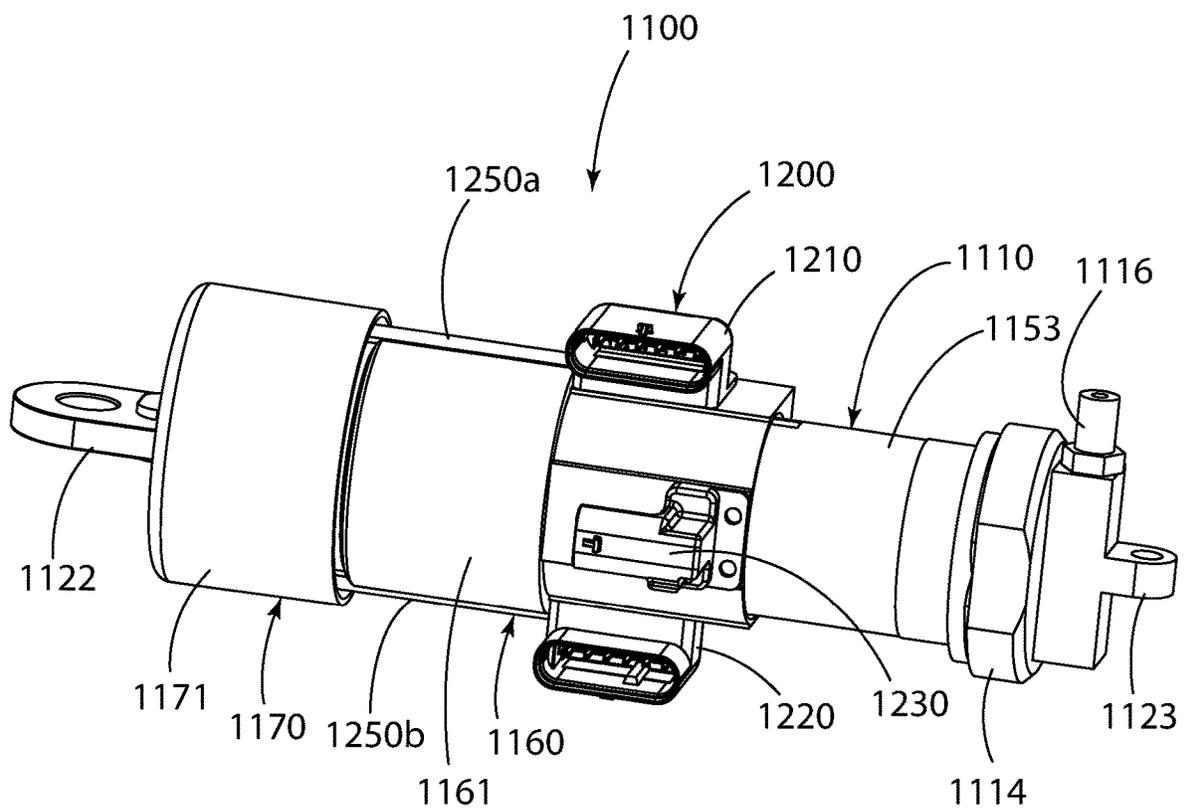
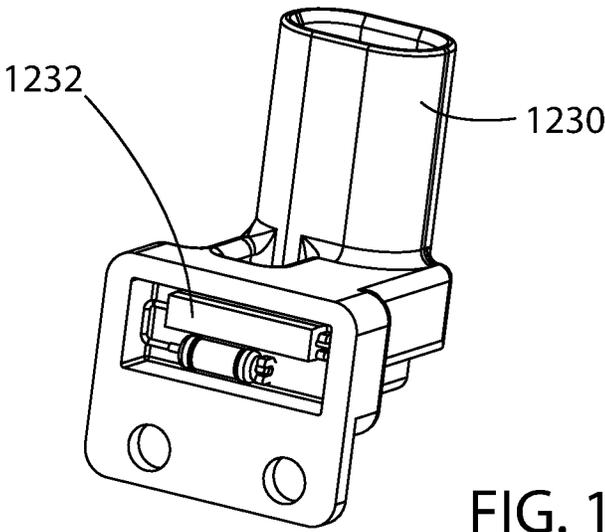
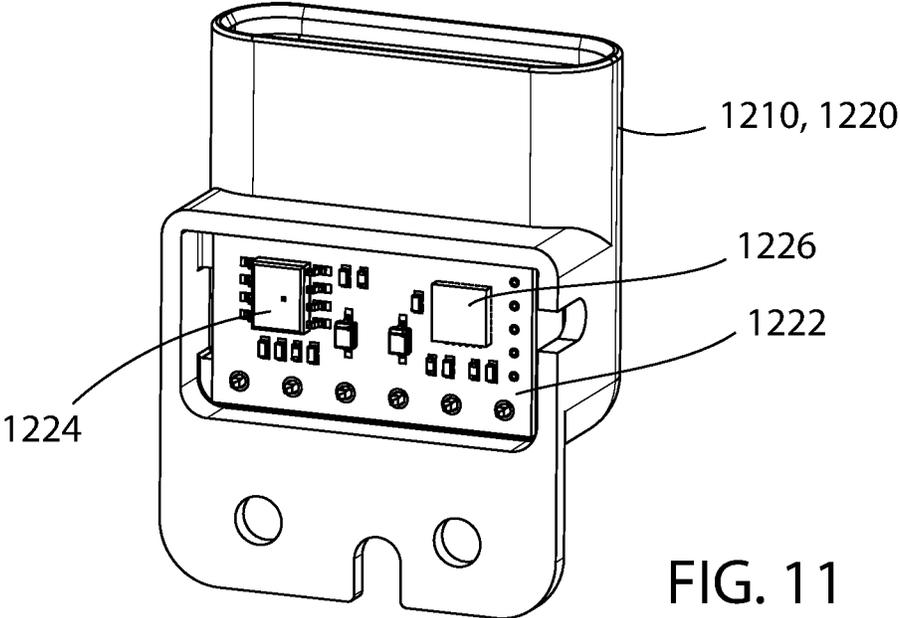


FIG. 10



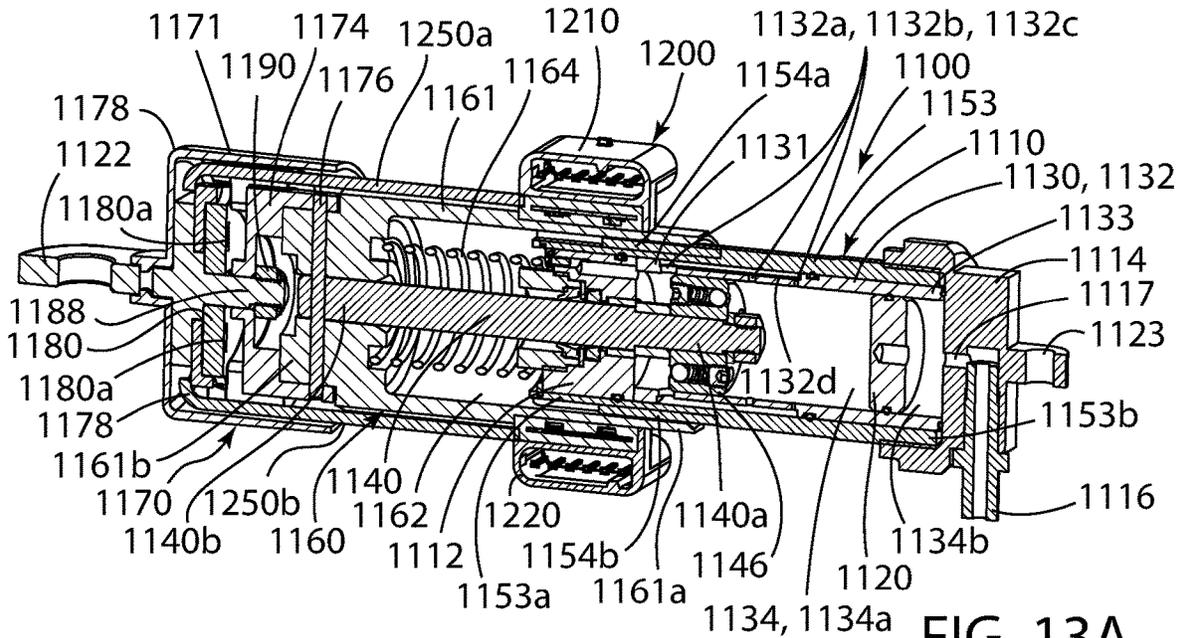


FIG. 13A

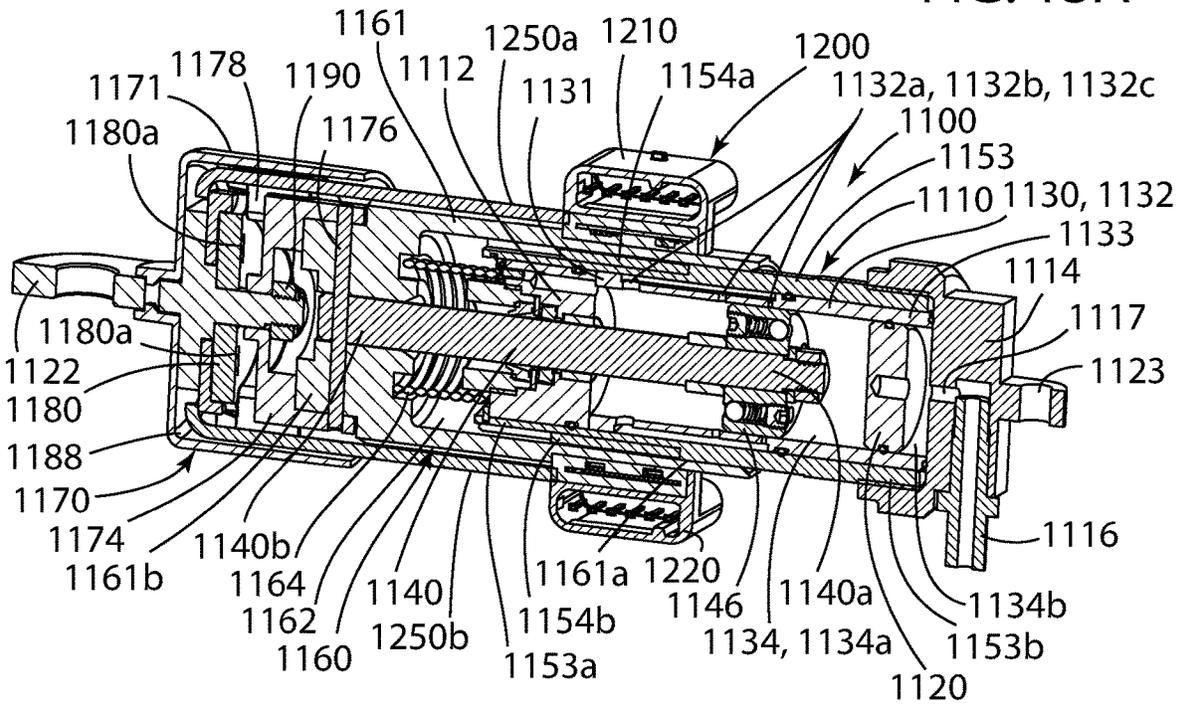


FIG. 13B

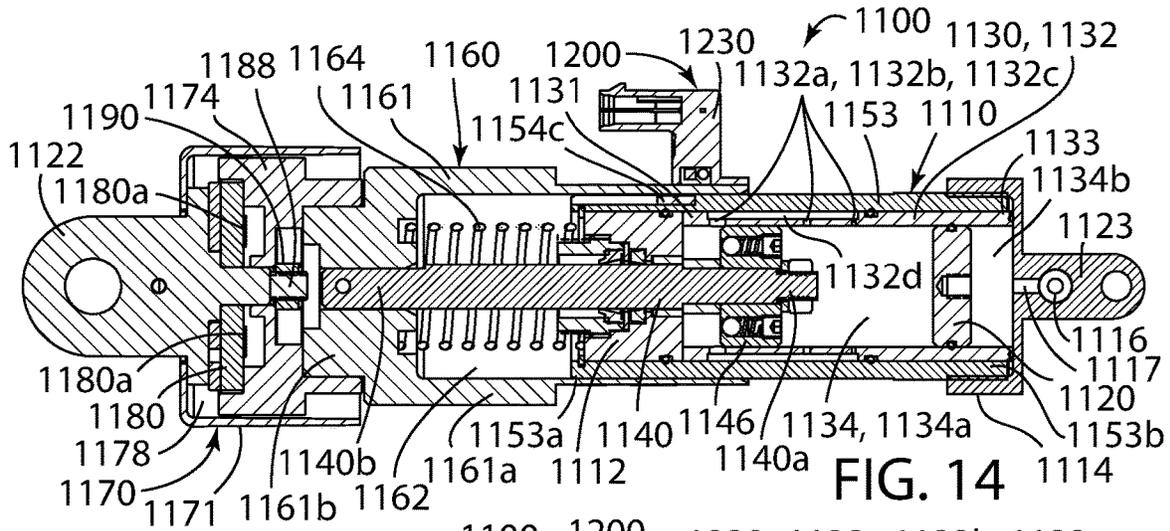


FIG. 14

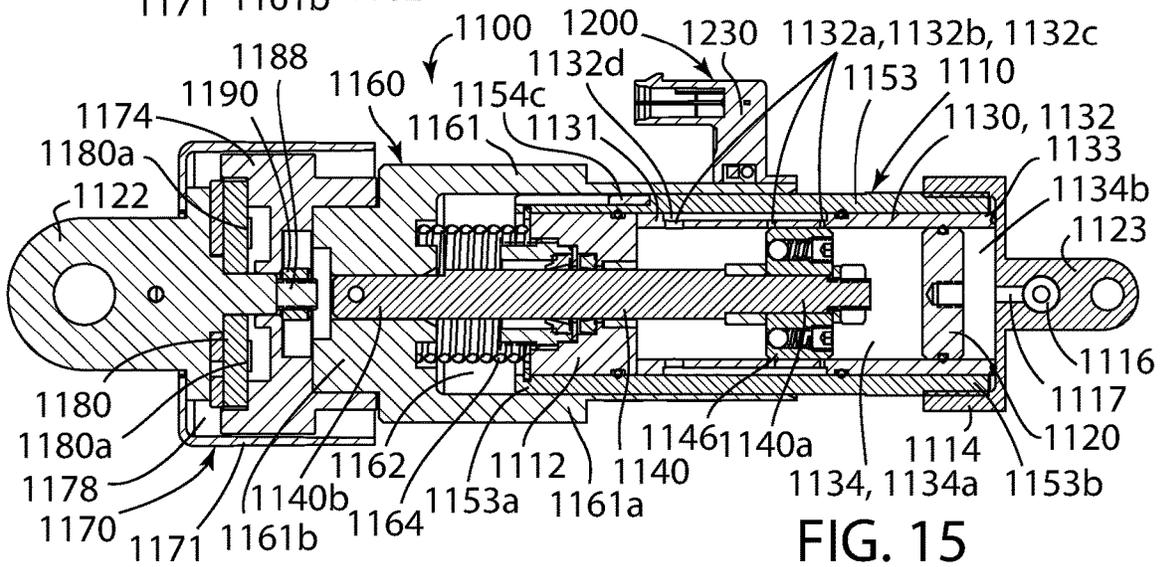


FIG. 15

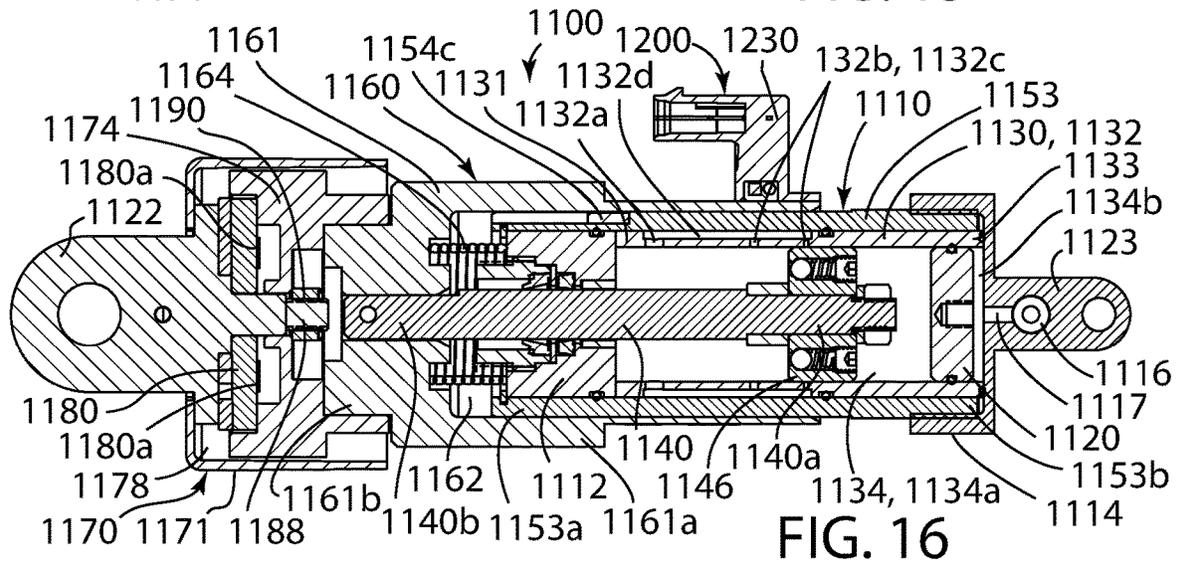
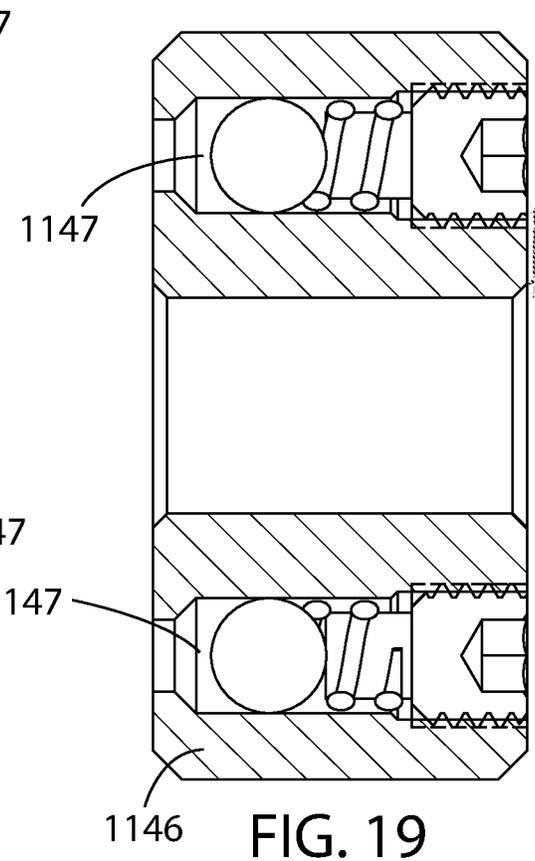
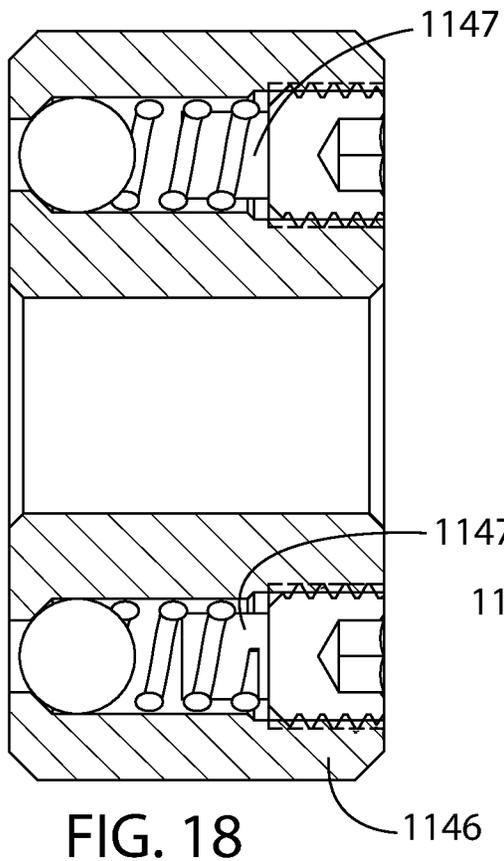
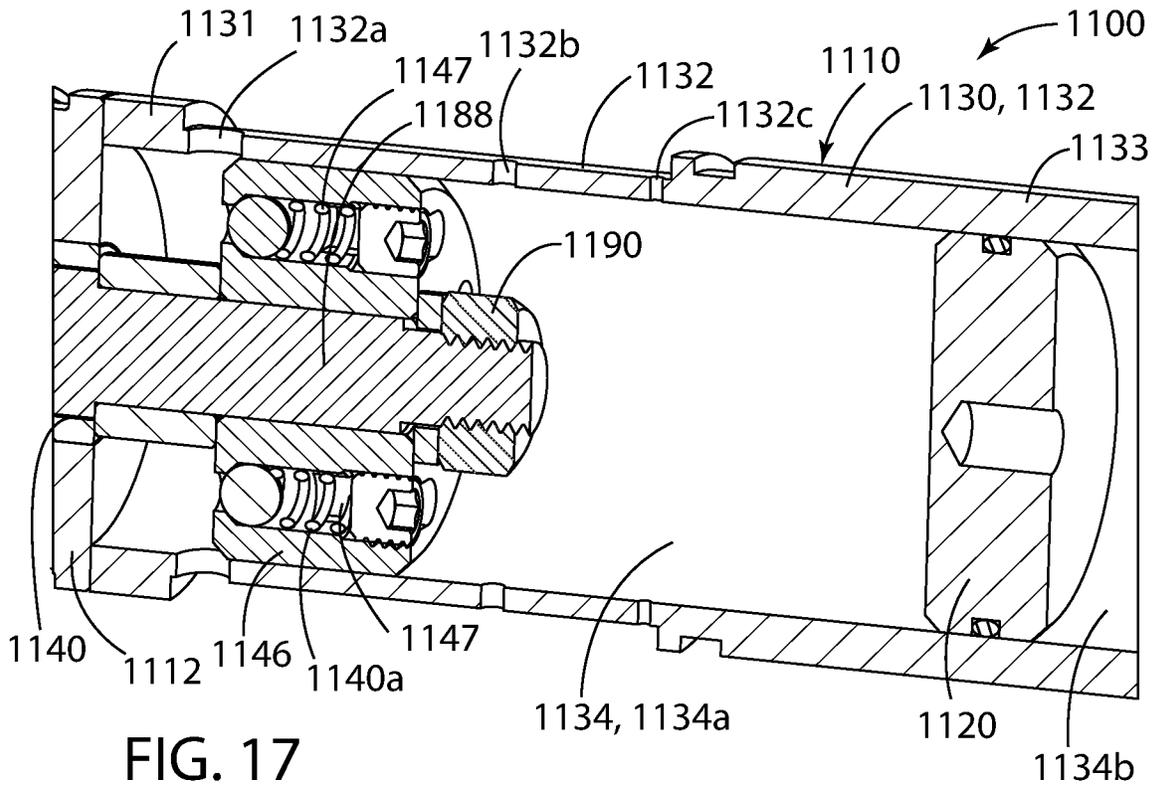


FIG. 16



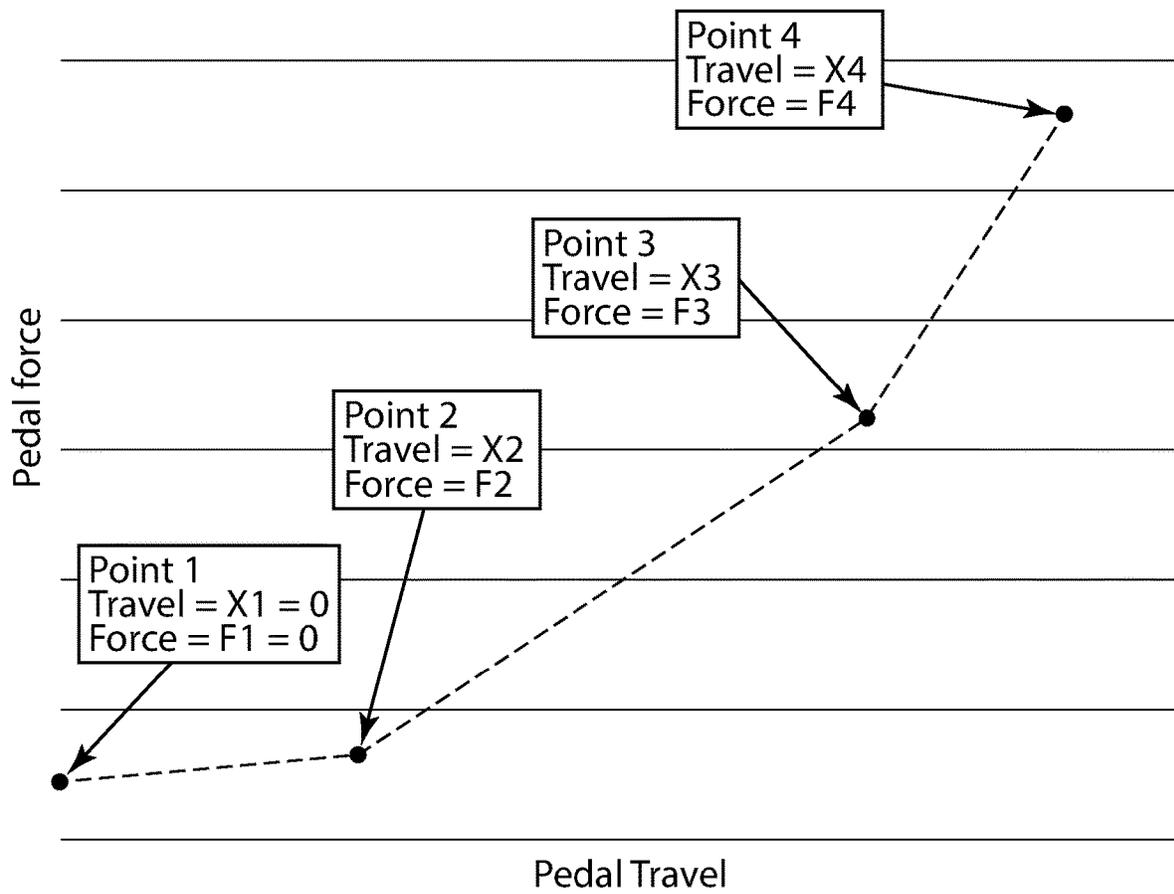


FIG. 20

**VEHICLE BRAKE PEDAL WITH PEDAL  
RESISTANCE ASSEMBLY AND  
FORCE/POSITION SENSOR**

CROSS-REFERENCE TO RELATED  
APPLICATIONS

This patent application claims priority and benefit of U.S. Provisional Patent Application Ser. No. 62/845,401 filed on May 9, 2019 and U.S. Provisional Patent Application Ser. No. 62/992,944 filed on Mar. 21, 2020, the disclosure and contents of which are expressly incorporated herein in their entireties by reference.

This patent application is also a divisional application which claims priority and benefit of U.S. application Ser. No. 16/867,733 filed on May 6, 2020 which is a continuation-in-part application of U.S. application Ser. No. 16/439,822 filed on Jun. 13, 2019, now U.S. Pat. No. 10,654,452 issued on May 19, 2020, which is a continuation application of U.S. application Ser. No. 15/876,772 filed on Jan. 22, 2018, now U.S. Pat. No. 10,343,657 issued on Jul. 9, 2019, the disclosures and contents of which are expressly incorporated herein in their entireties by reference.

FIELD

This invention relates to a vehicle brake pedal with a pedal resistance assembly and a force/position sensor.

BACKGROUND

Brake-by-wire vehicle brake pedals do not utilize a conventional vacuum or hydraulic system for braking.

There is a desire to replicate the feel of a conventional vacuum or hydraulic braking system in brake-by-wire vehicle brake pedals.

The present invention is directed to a brake-by-wire vehicle brake pedal including a pedal resistance assembly that replicates the resistance feel of a conventional vacuum or hydraulic braking system.

The present invention is also directed to a pedal resistance assembly that incorporates a pedal force/position sensor.

SUMMARY

The present invention is generally directed to a brake pedal assembly comprising a pedal and a pedal resistance force member operably coupled to the pedal and including a damper pedal resistance force module defining an interior fluid-filled cavity, a shaft extending through the damper module and including a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force, a spring pedal resistance force module adapted to generate a spring pedal resistance force, a pedal force sensing module mounted to the pedal resistance force member, a pedal position sensor mounted to the pedal resistance force member; and a pedal force sensor mounted to the pedal resistance force member.

In one embodiment, the spring pedal resistance force module and the pedal force sensing modules are located at opposed ends of the pedal resistance force member.

In one embodiment, the spring pedal resistance force module and the pedal force sensing modules are located at the same end of the pedal resistance force member.

In one embodiment, the pedal resistance force member includes a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the

shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the fixed sleeve and including first and second springs compressible in response to movement and contact with the shaft and the fixed sleeve respectively for generating the spring pedal resistance force.

In one embodiment, the pedal force sensing module is coupled to the moveable sleeve.

In one embodiment, the pedal resistance force member includes a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the moveable sleeve and including a first spring compressible in response to movement of the moveable sleeve for generating the spring pedal resistance force.

In one embodiment, the pedal force sensing module is coupled to the moveable sleeve.

In one embodiment, the pedal force sensing module includes a deflectable strain gauge plate with a deformable strain gauge element, the strain gauge plate being deflectable and the strain gauge element being deformable in response to the application of a force against the strain gauge plate.

In one embodiment, a bracket is coupled to the pedal and extending into the pedal force sensing module and into contact with the deflectable strain gauge, the bracket being adapted to exert a force against the deflectable strain gauge in response to the movement of the pedal.

In one embodiment, a magnet is coupled to the stationary sleeve, the pedal position sensor comprising a Hall Effect sensor mounted to the moveable sleeve and adapted for sensing changes in the magnetic field generated by the magnet for determining the position of the pedal in response to the movement of the Hall Effect sensor relative to the magnet.

The present invention is also directed to a pedal resistance force member for a brake pedal and comprising a damper pedal resistance force module defining an interior fluid-filled cavity, a shaft extending through the damper module and including a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force, a spring pedal resistance force module adapted to generate a spring pedal resistance force, a pedal force sensing module mounted to the pedal resistance force member, a pedal position sensor mounted to the pedal resistance force member, and a pedal force sensor mounted to the pedal resistance force member.

In one embodiment, the spring pedal resistance force module and the pedal force sensing modules are located at opposed ends of the pedal resistance force member.

In one embodiment, the spring pedal resistance force module and the pedal force sensing modules are located at the same end of the pedal resistance force member.

In one embodiment, the pedal resistance force member includes a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the fixed sleeve and including first and second springs compressible in response to movement and contact with the shaft and the fixed sleeve respectively for generating the spring pedal resistance force.

In one embodiment, the pedal force sensing module is coupled to the moveable sleeve.

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In one embodiment, the pedal resistance force member includes a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the moveable sleeve and including a first spring compressible in response to movement of the moveable sleeve for generating the spring pedal resistance force.

In one embodiment, the pedal force sensing module is coupled to the moveable sleeve.

In one embodiment, the pedal force sensing module includes a deflectable strain gauge plate with a deformable strain gauge element, the strain gauge plate being deflectable and the strain gauge element being deformable in response to the application of a force against the strain gauge plate.

In one embodiment, a bracket is coupled to a pedal and extends into the pedal force sensing module and into contact with the deflectable strain gauge, the bracket being adapted to exert a force against the deflectable strain gauge in response to the movement of the pedal.

In one embodiment, a magnet is coupled to the stationary sleeve, the pedal position sensor comprising a Hall Effect sensor mounted to the moveable sleeve and adapted for sensing changes in the magnetic field generated by the magnet for determining the position of the pedal in response to the movement of the Hall Effect sensor relative to the magnet.

Other advantages and features of the present invention will be more readily apparent from the following detailed description of the embodiment of the invention, the accompanying drawings, and the appended claims.

#### BRIEF DESCRIPTION OF THE DRAWINGS

These and other features can best be understood by the description of the accompanying FIGS as follows:

FIG. 1 is a simplified broken side elevational view of a vehicle brake pedal incorporating a first embodiment of a pedal resistance force assembly or member in accordance with the present invention;

FIG. 2 is a perspective view of the pedal resistance force assembly shown in FIG. 1;

FIG. 3 is a perspective view of one of the connectors with the position and force sensor assembly and associated sensor integrated circuits and wake-up switch;

FIGS. 4 and 7 are vertical cross-sectional views of the pedal resistance force assembly shown in FIG. 2 in its fully engaged braking position;

FIG. 5 is a vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 2 in its rest or disengaged or non-braking position;

FIG. 6 is a vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 2 in a first partially engaged braking position;

FIG. 8 is a graph depicting the pedal resistance force generated by the pedal resistance assembly shown in FIGS. 1-7 as a function of pedal travel;

FIG. 9 is a simplified broken side elevational view of a vehicle brake pedal incorporating another embodiment of a pedal resistance force assembly or member in accordance with the present invention;

FIG. 10 is a perspective view of the pedal resistance force assembly shown in FIG. 9;

FIG. 11 is a perspective view of one of the connectors incorporating the position and force sensor integrated circuits of the pedal resistance force assembly of FIG. 9;

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FIG. 12 is a perspective view of another of the connectors incorporating the wake-up switch of the position and force sensor integrated circuits of the pedal resistance force assembly shown in FIG. 9;

FIG. 13A is a vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 9 in its rest or disengaged or non-braking position;

FIG. 13B is a vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 9 in its fully engaged braking position;

FIG. 14 is a vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 9 in a first partially engaged braking position;

FIG. 15 is a vertical cross-sectional view of the pedal force resistance force assembly shown in FIG. 9 in a second partially engaged braking position;

FIG. 16 is another vertical cross-sectional view of the pedal resistance force assembly shown in FIG. 9 in its fully engaged braking position;

FIG. 17 is an enlarged broken vertical cross-sectional view of the pedal resistance force assembly in the rest or disengaged or non-braking position as shown in FIG. 13;

FIG. 18 is an enlarged vertical cross-sectional view of the position of the check valves of the piston of the pedal resistance force assembly in the FIG. 13A-16 positions of the pedal resistance force assembly;

FIG. 19 is an enlarged vertical cross-sectional view of the position of the check valves in the piston of the pedal resistance force assembly during the return of the pedal from its FIG. 16 position to its FIG. 13A position; and

FIG. 20 is a graph depicting the pedal resistance force generated by the pedal resistance assembly shown in FIGS. 9-16 as a function of pedal travel.

#### DESCRIPTION OF THE EMBODIMENTS

FIGS. 1-7 depict a first embodiment of a vehicle brake pedal assembly 10 incorporating a pedal resistance force assembly or module or member 100 in accordance with the present invention.

The vehicle brake pedal assembly 10 includes a base/bracket 12, an elongate brake pedal 14 pivotally connected for clockwise/engaging/braking and counterclockwise/disengaging/non-braking rotation and movement relative to the pedal base/bracket 12. The pedal resistance force assembly 100 is operably coupled to the pedal assembly 10 in a relationship extending between the base/bracket 12 and the pedal 14 and further in a relationship with a first end bracket 122 thereof operatively coupled to the pedal 14 and a second opposed end bracket 123 coupled to the pedal base/bracket 12.

The pedal resistance assembly 100 is generally in the form and shape of an elongate hollow cylinder or housing or tube initially comprising an interior liquid-filled cylinder or tubular damper or resistance force module 110 adapted to provide a velocity-dependent force response and including a first central generally cylindrical elongate hollow interior cylinder or tubular housing or sleeve 130 including an exterior circumferential wall 132 defining and forming an interior hollow elongate cylindrically or tubular shaped receptacle or cavity or chamber 134 and further defining opposed ends 131 and 133.

A first sealing cap or cartridge 112 covers and seals a first end of the sleeve 130 of the damper module 110. A second opposed and spaced apart sealing cap or cartridge 114 covers and seals a second opposed end of the sleeve 130 of the damper module 110. The cavity or chamber 134 contains a

damper fluid (not shown) which, in one embodiment, can be a propylene glycol and water mixture.

The pedal resistance assembly 100 further comprises an elongate shaft 140 extending through the interior of the chamber 134 of the sleeve 130 of the damper module 110. The shaft 140 includes a first end 140a extending through a central aperture defined in the cap 112 and a second opposed end 140b of the shaft 140 extending through a central aperture defined in the opposed cap 114.

A piston 146 extends around a central portion or segment of the shaft 140 and is located in the fluid cavity 134 between the two end sealing caps 112 and 114. The piston 146 is fixed on the shaft 140 and is moveable linearly in the interior of the fluid cavity 134 in response to the back and forth linear movement of the shaft 140.

The piston 146 includes a dual rod structure adapted to maintain a constant fluid volume during the stroke or movement thereof. The interior surface of the wall 132 of the sleeve 130 of the damper module 110 includes variable geometry grooves 128 that allow the damping function to vary with distance or movement of the piston linearly within the interior of the sleeve 130. The pedal resistance assembly 100 still further comprises a second hollow cylindrical or tubular sleeve or housing 153 surrounding the sleeve 130 of the damper module 110. The end 140b of the shaft 140 extends into the interior of the sleeve or housing 153. The sleeve 153 includes opposed ends 153a and 153b. The damper module sleeve 130 is located in the end 153a of the sleeve 130.

A pair of elongate sensor magnets 154a and 154b are mounted on a magnet carrier 300 surrounding and fixed to the end 153a of the sleeve 153. The magnets 154a and 154b are located in a diametrically opposed relationship on opposed sides of the magnet carrier 300 and thus on diametrically opposed sides of the pedal resistance assembly 110.

A third hollow cylindrical or tubular sleeve or guide 155 surrounds the second sleeve or housing 153. The sleeve or guide 155 includes opposed ends 155a and 155b. A collar 156 is defined at the one end 155a of the sleeve or guide 155. The end 140a of the shaft 140 extends through a central aperture defined in the collar 156.

A ring 159 surrounds and is fixed to the end 155b of the sleeve or guide 155.

The pedal resistance assembly 100 still further comprises a spring pedal resistance force module 160 at one end thereof that is coupled to and surrounds the end 153b of the sleeve 153. The pedal resistance module 160 includes the bracket 123 which includes an interior cylindrical collar 162 surrounding the end 153b of the sleeve 153 and a cylindrical pin or projection or finger 163 extending into the interior of the end 153b of the sleeve 153. The pedal resistance module 160 further includes an interior cap 163a that is moveable within the interior of the end 153b of the sleeve 153. A ring 157 protruding inwardly from the interior face of the wall of the sleeve 153 defines a stop that limits the movement of the cap 163a in the interior of the sleeve 153.

A first compressible and expandable helical spring 164 extends around the pin 163, is located in the interior of the end 153a of the sleeve 153 and includes opposed ends abutted against the interior collar 162 and the interior of the bracket 123 respectively.

A second compressible and expandable helical spring 165 extends around the exterior of the end 153b of the sleeve 153 and includes opposed ends abutted respectively against the collar 162 of the bracket 123 and the ring 159 surrounding and fixed to the end 155b of the sleeve or guide 155.

An exterior shroud 166 surrounds and covers the spring 165. A screw 167 secures the shroud 166 to the bracket 123.

The pedal resistance assembly 100 still further comprises a pedal force module 170 coupled to and partially surrounding the collar 156 at the one end 155a of the sleeve or guide 155.

Thus, in the embodiment shown, the pedal resistance module 160 and the pedal force module 170 are positioned in a co-linear relationship along the longitudinal axis of the pedal resistance assembly 100 and located at opposed distal ends of the pedal resistance assembly 100 in a relationship with the damper or resistance force module 110 located between the pedal resistance module 160 and the pedal force module 170, all in a co-linear relationship relative to each other.

The pedal force module 170 includes an interior strain gauge housing 172 that includes a center plate 173 and a circumferential collar 174 surrounding the collar 156 of the sleeve or guide 155. An elongate spring pin 176 extends through the collars 174 and 156 and the end 140a of the shaft 140. The housing 172 defines an interior chamber or cavity or receptacle for a pair of deformable Wheatstone bridge strain gauge discs 180 and 182 separated by a spacer 184 and including strain gauge elements (not shown) mounted thereon as known in the art.

The bracket 122 includes a pin 188 that extends through the strain gauge discs 180 and 182 and through an aperture defined in the center plate 173 of the housing 172. A preload lock nut 190 surrounds the end of the pin 188, is abutted against the plate 173, and secures the pin 188 and thus the bracket 122 to the housing 172. A shroud 192 surrounds the housing 172.

The pedal resistance assembly 100 still further comprises a combination position and force sensor/sensing assembly or module 200 coupled to the exterior of the damper module 110 and, more specifically, to the exterior of the guide sleeve 155 of the damper module 110. The assembly 200 comprises a pair of diametrically opposed connector assemblies 210 and 220 mounted to the exterior of the guide sleeve 155. As shown in FIG. 3, each of the connector assemblies 210 and 220 defines an interior housing for a printed circuit board 222 including a position sensor Hall Effect IC 224 and a pedal force sensor IC 226 mounted thereon. The pedal resistance assembly 110 includes a pair of connector assemblies 210 and 220 and position sensor Hall Effect ICs and the pair of magnets 154a and 154b for redundancy reasons.

The connector assembly 210 also defines a housing for a position sensor wake-up switch 230 which, in one embodiment, may be a Reed type switch. The switch 230 is adapted to wake-up the respective position sensor Hall Effect ICs 224 in response to the application of an initial braking force against the pedal 14.

A switch connector assembly 240 is also mounted to the exterior of the damper module 110 and, more specifically, to exterior of the sleeve 155 of the damper module 110.

Connector wires 250a and 250b extend between the respective strain gauge elements 180 and 182 and the respective strain gauge sensor ICs 226 mounted on the respective printed circuit boards 222 in the interior of the respective connector assemblies 210 and 220. Another connector wire 250c extends between the wake-up switch 230 and the switch connector assembly 240.

The combination of the pedal damper module 110 and the pedal resistance module 160 respectively are adapted to create and generate an increasing resistive force on the pedal 14 in response to the travel or movement or stroke of the pedal 14 during operation of a vehicle for either applying the

brakes and increasing the resistance force or releasing the brakes and decreasing the resistance force as represented by the lines A and B in the graph of FIG. 8.

The combination of the damper module 110 and the spring 165 of the spring resistance module 160 create and generate an initial increasing resistance or feel force on the brake pedal 14 that is represented by the point A in the graph of FIG. 8. This initial increasing resistance or feel force is generated in response to the depression of the pedal 14 which, as shown in FIG. 6, results in the forward movement of the bracket 122 which in turn results in the forward movement of the force module 170 which in turn results in the forward sliding movement relative to the sleeve 130 of the damper module 110 and the sleeve 153 which in return results in the forward sliding movement of the shaft 140 coupled to the sleeve 155 which in return results in the movement of the piston 146 in the interior fluid filled cavity 134 of the damper module 110 which in return generates the initial increasing dampening resistive force against the pedal 14.

An additional resistive force is generated against the pedal 14 as a result of the compression of the spring 165 in response to the forward sliding movement of the sleeve 155 which results in the forward movement of the ring 159 mounted thereon which causes the application of a compressive force against the one end of the spring 165 abutted against the ring 159 which in turn results in the compression of the spring 165 and the generation of a resistive force against the pedal 14.

The additional depression of the pedal 14 results in the additional forward movement of the sleeve 155 and the shaft 140 which results in the additional compression of the spring 165 and still further results in the abutting contact of the end 140b of the shaft 140 with the cap 163a which in turn and as a result of the further forward movement of the sleeve 155 and the shaft 140 results in the forward movement of the cap 163a which in turn results in the compression of the spring 164 which results in the generation of a still further increased resistive force against the pedal 14 which is represented by the line B in the graph of FIG. 8.

Although not described or shown herein in detail, it is understood that the lines B and A also represent the decreased pedal resistance force on the pedal 14 generated when the vehicle operator removes foot pressure from the pedal 14 to release the brakes of the vehicle.

Additionally, the forward movement of the sleeve 155 results in the forward movement of the connector assemblies 210 and 220 mounted thereon and thus the movement of the position sensor Hall Effect ICs 224 mounted on the respective printed circuit boards 222 thereof relative to the respective stationary magnets 154a and 154b on the magnet carrier 300 which results in the sensing by the respective Hall Effect ICs 224 of the changes in the magnitude and/or direction of the magnetic fields of the respective magnets 154a and 154b which results in the generation of respective electrical signals which are transferred to a control unit (not shown) for measuring and determining the position of the sleeve 155 and thus the position of the pedal 14.

The forward movement of the connector assembly 210 also results in the movement of the reed switch 230 which in turn results in the activation of the switch 230 which in turn results in the wake-up of the respective position sensor ICs 224 upon initial depression of the pedal 14.

Moreover, the depression of the pedal 14 results in the forward movement of the bracket 122 which in turn results in the bracket 122 applying a force against the respective strain gauge discs 180 and 182 which in return results in a

deformation or deflection of the respective discs 180 and 182 that is sensed by one or more strain gauge elements 180a and 182a located on one or both of the exterior surfaces of the discs 180 and 182 which results in a change of voltage that is sensed by the respective strain gauge elements 180a and 182a and the generation of appropriate electric signals which are transferred to the pedal force sensor IC 224 on the respective printed circuit board assemblies 222 of the respective connector assemblies 210 and 220 which signals are transferred to a control unit (not shown) for measuring and determining the force being applied to the pedal 14. The pedal resistance assembly 100 includes a pair of force sensor assemblies for redundancy reasons.

FIGS. 9-19 depict a second embodiment of a vehicle brake pedal assembly 1010 incorporating a pedal resistance force assembly or module or member 1100 in accordance with the present invention.

The vehicle brake pedal assembly 1010 includes a base/bracket 1012, an elongate brake pedal 1014 pivotally connected for clockwise/engaging/braking and counterclockwise/disengaging/non-braking rotation and movement relative to the pedal base/bracket 1012. The pedal resistance assembly 1100 is operably coupled to the pedal assembly 1010 in a relationship extending between the base/bracket 1012 and the pedal 1014 and more specifically in a relationship with a first end bracket 1122 thereof operatively coupled to the pedal 1014 and a second opposed end bracket 1123 coupled to the pedal base/bracket 1012.

The pedal resistance assembly 1100 which is generally in the form and shape of an elongate hollow cylinder or housing or tube initially comprising a fixed or stationary liquid and air filled damper pedal resistance force module 1110 adapted to provide a velocity-dependent force response and including a first central generally cylindrical elongate hollow interior housing or sleeve or tube 1130 including an interior circumferential wall 1132 defining and forming an interior hollow elongate cylindrically shaped receptacle or cavity or chamber 1134 and further defining opposed ends 1131 and 1133.

The housing or sleeve 1130, and more specifically, the circumferential wall 1132 thereof, also includes a plurality, and more specifically in the embodiment shown three, spaced apart through-holes or apertures 1132a, 1132b, and 1132c extending around the circumference of the wall 1132 and are radially spaced along the length of the wall 1132.

The housing or sleeve 1130, and more specifically the circumferential wall 1132 thereof, also includes and defines a circumferential exterior recessed area or groove 1132d in communication with the respective holes or apertures 1132a, 1132b, and 1132c.

A first sealing cap or cartridge 1112 covers and seals the first end 1131 of the sleeve 1130 of the damper module 1110. A second opposed and spaced apart cap or cartridge 1114 covers and seals the second end 1133 of the sleeve 1130 of the damper module 1110. The bracket 1123 is unitary with the cap 1114.

The cavity or chamber 1134 includes an interior moveable generally cylindrical sealing plug or gasket or floating tan piston 1120 that separates the interior of the cavity or chamber 1134 into a first chamber section 1134a on one side of the plug or gasket 1120 that contains a damper fluid which, in one embodiment, can be a propylene glycol and water mixture and a second chamber section 1134b on the other side of the plug or gasket or piston 1120 that contains compressed air.

The cap or cartridge **1114** incorporates a Schrader or the like air pressure valve **1116** adapted for connection to a source of compressed air. The valve **1116** is in communication with an aperture or conduit **1117** defined in the interior of the cap or cartridge **1114** which, in turn, is in communication with the interior of the second chamber section **1134b** and adapted for the supply of compressed air into the interior of the second chamber section **1134b** as discussed in more detail below.

The pedal resistance assembly **1100** further comprises an elongate shaft **140** extending through the interior of the chamber **1134** of the damper or resistance force module **1110**, and more specifically through the interior of the chamber section **1134a** of the sleeve **1130** of the damper module **1110**. The shaft **140** includes a first end **1140a** and an opposed second end **1140b**.

A piston **1146** extends around the first end **1140a** of the shaft **140** and is located in the fluid cavity section **1134a** of the interior chamber **1134** between the sealing cap **1112** and the sealing gasket or plug **1120**. The piston **1146** is fixed on the shaft **140** and is moveable linearly in the interior of the fluid cavity section **1134a** of the chamber **1134** in response to the back and forth linear movement of the shaft **140** as explained in more detail below.

The piston **1146** includes a plurality of check valves **1147** incorporated therein and extending between opposed sides of the piston **1146** and adapted to allow the liquid in the first chamber section **1134a** to move between the opposed sides of the piston **1146** as also described in more detail below.

The pedal resistance assembly **1100** and, more specifically the damper pedal resistance force module **1110** thereof, still further comprises a second hollow cylindrical or tubular stationary or fixed sleeve or housing **1153** surrounding and fixed to the exterior of the circumferential wall **1132** of the sleeve **1130** of the damper module **1110**. The sleeve or housing **1153** includes opposed ends **1153a** and **1153b**. The end **1153a** of the sleeve **1153** extends and protrudes fore of the end **1131** of the sleeve **1130**. The end **1153b** of the sleeve **1153** surrounds the end **1133** of the sleeve **1130**. The cap **1114** surrounds and is fixed to the end **1153b** of the sleeve **1153**.

The end **1153a** of the sleeve **1153** surrounds the first sealing cap or cartridge **1112** which covers and seals the first end **1131** of the sleeve **1130** of the damper module **1110**.

The sleeve **1153** surrounds and is fixed to the sleeve **1130** in a relationship wherein the groove **1133d** defined in the sleeve **1130** and the interior surface of the wall of the sleeve **1153** defines a fluid flow chamber as described in more detail below.

A pair of elongate and diametrically opposed sensor magnets **1154a** and **1154b** are located in respective grooves defined in the exterior face of the wall of the sleeve **1153**. A switch magnet **1154c** is located in another groove defined in the exterior wall of the sleeve **1153**. The switch magnet **1154c** is positioned on the sleeve **1153** between and spaced ninety degrees from the sensor magnets **1154a** and **1154b**.

The pedal resistance assembly **1100** still further comprises a spring pedal resistance force module **1160** defined by a moveable and slidable sleeve **1161** including a first end **1161a** surrounding the end **1153a** of the sleeve **1153** of the damper or resistance force module **1110**. The sleeve **1160** defines an opposed end or radial collar or base **1161b**. The sleeve **1161** also defines an interior chamber or cavity **1162**.

A compressible and expandable helical spring **1164** is located in the interior chamber or cavity **1162**. A first end of the spring **1164** is abutted against the end of the interior cap **1112**. A second end of the spring **1164** is abutted against a

face of the collar **1160b** of the sleeve **1161**. The spring **1164** is compressible in response to the depression of the pedal **1014** and the resultant movement of the sleeves **1161** and **1153** relative to each other as described in more detail below.

The end **1140b** of the shaft **140** extends and is fixed in the end or collar **1160b** of the sleeve **1161**.

The pedal resistance assembly **1100** still further comprises a pedal force module **1170** coupled to and partially surrounding the end **1160b** of the sleeve **1161**.

The pedal force module **1170** includes an exterior collar or circumferential wall or jacket **1171** defining an interior hollow housing or cavity **1178** that houses a deformable Wheatstone bridge strain gauge disc **1180** including strain gauge elements (not shown) mounted thereon as known in the art.

The pedal force module **1170** further comprises an interior bracket **1174** located in the cavity **1178** and coupled to and abutted against the collar **1160b** of the sleeve **1161**.

An elongate pin **1176** extends successively through the end **1140b** of the shaft **140**, the collar **1160b** of the sleeve **1160**, and the bracket **1174** of the pedal force module **1170**.

The bracket **1122** is coupled to and extends into the interior of the collar **1171** of the pedal force module **1170**. The bracket **1122** includes an outwardly projecting pin **1188** that extends from the bracket **1122** into the interior of the collar **1171**, through the strain gauge disc **1180**, and into the interior bracket **1174**. A preload lock nut **1190** surrounds and is coupled to the distal end of the pin **1188** and secures the pin **1188** to the bracket **1174**.

Thus, in the embodiment shown, the pedal resistance module **1160** and the pedal force module **1170** are positioned in a co-linear relationship along the longitudinal axis of the pedal resistance assembly **1100** and located at the same distal end of the pedal resistance assembly **1100** in an adjoining side-by-side co-linear relationship with the pedal resistance module **1160** in an adjoining side-by-side co-linear relationship with the damper module **1110** and, still more specifically, in a side-by-side co-linear relationship with the pedal resistance module **1160** located between the pedal force module **1170** and the damper module **1110** of the pedal resistance assembly **1100**.

The pedal resistance assembly **1100** still further comprises a combination position and force sensor assembly **1200** coupled to the exterior of the pedal resistance module **1160** and, more specifically, to the exterior of the sleeve **1161** of the pedal resistance module **1160** and more specifically comprises a plurality, and more specifically three, connector assemblies **1210**, **1220**, and **1230** mounted to the exterior of the sleeve **1161**.

Each of the connector assemblies **1210** and **1220** defines a housing for a printed circuit board **1222** including a position sensor Hall Effect IC **1224** and a pedal force sensor IC **1226** mounted thereon. The pedal resistance assembly **1110** includes a pair of connector assemblies **1210** and **1220** and position sensor Hall Effect ICs and the pair of magnets **1154a** and **1154b** for redundancy reasons.

The connector assembly **1230** defines a housing for a position sensor wake-up switch **1232** which, in one embodiment, may be a Reed type switch. The switch **1232** is adapted to wake-up the respective position sensor Hall Effect ICs **1224** in response to the application of an initial braking force against the pedal **1014**.

Connector wires **1250a** and **1250b** extend between the strain gauge element **1180** and the respective strain gauge sensor ICs **1226** mounted on the respective printed circuit boards **1222** in the interior of the respective connector assemblies **1210** and **1220**. Another pair of connector wires

(not shown) extends between the wake-up switch **1232** in the connector assembly **1230** and the Hall Effect ICs **1224** in the respective connector assemblies **1210** and **1220**.

The combination of the damper and resistance modules **1110** and **1160** respectively are adapted to create and generate an increasing resistive force on the pedal **1014** in response to the travel or movement of the pedal **1014** during operation of a vehicle for either applying the brakes and increasing the resistance force or releasing the brakes and decreasing the resistance force as represented in the graph of FIG. **20**.

Point **1** in the graph of FIG. **20** represents the zero force **F1** against the brake pedal **1014** in the Zero travel **x1** position of the brake pedal **1014** in the disengaged or non-braking position of the pedal **1014** as shown in FIG. **9** and disengaged or non-braking position of the pedal resistance force assembly or module or member **1100** as shown in FIG. **13A**.

The combination of the damper module **1110** and the spring **1164** of the spring resistance module **1160** are adapted to create and generate an initial resistance or feel force **F2** on the brake pedal **1014** that is represented by the Point **2** in the graph of FIG. **20** in response to the depression of the pedal **1014** and resultant movement of the pedal resistance force assembly or module or member **1100** from its FIG. **13A** and Point **1** position to its first partially engaged braking Point **2** Travel **X2** brake pedal position as shown in FIG. **14**.

This initial resistance or feel force is generated in response to the depression of the pedal **1014** which, as shown in FIG. **14**, results in the forward movement of the bracket **1122** which in turn results in the forward movement of the force module **1170** which in turn results in the forward sliding movement of the sleeve **1161** relative to the sleeves **1130** and **1153** of the damper module **1110** which in turn results in the forward sliding movement of the shaft **1140** coupled to the sleeve **1161** which in turn results in the movement of the piston **1146** in the interior fluid filled cavity **1134** of the damper module **1110** which in turn generates the initial dampening resistive force against the pedal **1014**.

An initial spring resistive force is also generated against the pedal **1014** as a result of the compression of the spring **1164** in response to the forward sliding movement of the sleeve **1161**.

The additional depression of the pedal **1014** and the resultant movement of the pedal resistance force assembly or module or member **1100** from its FIG. **14** Point **2** position to its FIG. **15** Point **3** Force **F3** against the brake pedal **1014** and Travel **X3** engaged brake pedal position results in an additional increase in the pedal resistance force against the pedal **1014** as shown in FIG. **20**.

Specifically, and referring to FIGS. **14** and **15**, the additional forward movement of the sleeve **1161** results in an additional compression of the spring **1164** which results in the application of an additional spring resistive force against the pedal **1014**.

The additional forward movement of the sleeve **1160** also results in the additional forward movement of the shaft **1140** which results in the additional forward movement of the piston **1146** in the interior fluid filled cavity **1134** of the damper module **1110** which in turn generates and creates an additional dampening resistive force against the pedal **1014**.

Also, and referring to FIG. **17**, it is understood that the movement of the piston **1146** between the FIG. **13A** and FIG. **15** positions results in the movement of the fluid from the portion of the chamber **1134** located fore of the piston **1146** through the respective holes **1132a, b, c** and the

chamber **1132d** and into the portion of the chamber cavity **1134** located aft of the piston **1146** for the purpose of allowing equalization of the fluid volume within the interior of the chamber **1134** in response to movement of the piston **1146** in the chamber **1134**.

The still further depression of the pedal **1014** and the resultant movement of the pedal resistance force assembly or module or member **1100** from its FIG. Point **3** position to its FIG. **16** Point **4** Force **F4** against the brake pedal **1014** and Travel **X4** brake pedal position results in a still further increase in the pedal resistance force against the pedal **1014** as shown in FIG. **20**.

Specifically, and referring to FIGS. **15** and **16**, the still further forward movement of the sleeve **1160** results in a still further additional compression of the spring **1164** which results in the application of a still further additional spring resistive force against the pedal **1014**.

The still further additional forward movement of the sleeve **1161** also results in the still further additional forward movement of the shaft **1140** which results in the additional forward movement of the piston **1146** in the interior fluid filled cavity **1134** of the damper module **1110** which in turn generates and creates a still further additional dampening resistive force against the pedal **1014**.

As shown in FIGS. **14-16**, the forward movement of the piston **1146** within the chamber **1134** results in the blocking of successive ones of the fluid holes **1132b** and **1132c** defined in the wall **1132** of the sleeve **1130** which in turn results in a build-up in the pressure of the fluid in the chamber **1134** which in turn results in the forward movement of the second piston **1120** in the chamber **1134** which in turn results in an increase in the pressure of the air located in the chamber section **1134b** of the chamber **1134** which in turn results in the further additional increase in the dampening resistance force against the pedal **1014**.

Although not described or shown herein in detail, it is understood that the Points **4, 3, 2, and 1** in FIG. **20** also represent the decreased pedal resistance force on the pedal **1014** generated when the vehicle operator removes foot pressure from the pedal **1014** to release the brakes of the vehicle.

In this regard, it is understood that the removal of foot pressure from the pedal **1014** results in the rearward movement of the piston **1146** in the chamber **1134** from its FIG. **16** position back to its FIG. **13A** position which results in the movement of the piston check valves from their FIG. **18** closed position to their FIG. **19** open position in which the fluid located in the aft portion of the chamber **1134** is allowed to flow through the check valves **1147** and back into the fore portion of the chamber **1134**.

Additionally, and independently, it is understood that the forward movement of the sleeve **1160** results in the forward movement of the connector assemblies **1210** and **1220** mounted thereon and thus the movement of the position sensor Hall Effect ICs **1224** mounted on the respective printed circuit boards **1222** relative to the respective stationary magnets **1154a** and **1154b** which results in the sensing by the respective Hall Effect ICs **1224** of the changes in the magnitude and/or direction of the magnetic fields of the respective magnets **1154a** and **1154b** which results in the generation of respective electrical signals which are transferred to a control unit (not shown) for measuring and determining the position of the sleeve **1155** and thus the position of the pedal **1014**.

The forward movement of the connector assembly **1230** also results in the movement of the reed switch **1232** relative to the switch magnet **1154c** which in turn results in the

activation of the switch **1232** which in turn results in the wake-up of the respective position sensor ICs **1224** upon initial depression of the pedal **1014**.

Moreover, the depression of the pedal **1014** results in the forward movement of the bracket **1122** which in turn results in the application of a force against the strain gauge disc **1180** which in turn results in a deformation or deflection of the disc **1180** that is sensed by one or more strain gauge elements **1180a** located on one or both of the exterior surfaces of the disc **1180** which results in a change of voltage that is sensed by the respective strain gauge elements **1180a** and the generation of appropriate electric signals which are transferred to the pedal force sensor IC **1224** on the respective printed circuit board assemblies **1222** of the respective connector assemblies **1210** and **1220** which signals are transferred to a control unit (not shown) for measuring and determining the force being applied to the pedal **1014**. The pedal resistance assembly **1100** includes a pair of force sensor assemblies for redundancy reasons.

Numerous variations and modifications of the embodiments of the pedal resistance assembly and pedal force/position sensors of the present invention as described above may be effected without departing from the spirit and scope of the novel features of the invention. It is to be understood that no limitations with respect to the embodiments illustrated herein are intended or should be inferred. It is, of course, intended to cover by the appended claims all such modifications as fall within the scope of the claims.

What is claimed is:

1. A brake pedal assembly comprising:

a pedal; and

a pedal resistance force member operably coupled to the pedal and including:

a damper pedal resistance force module defining an interior fluid-filled cavity;

a shaft extending through the damper module and including a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force;

a spring pedal resistance force module adapted to generate a spring pedal resistance force;

a pedal force sensing module mounted to the pedal resistance force member;

a pedal position sensor mounted to the pedal resistance force member;

a pedal force sensor mounted to the pedal resistance force member, and

the pedal resistance force member including a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the fixed sleeve and including first and second springs compressible in response to movement and contact with the shaft and the fixed sleeve respectively for generating the spring pedal resistance force,

wherein the pedal force sensing module is coupled to the moveable sleeve, and

wherein the spring pedal resistance force module and the pedal force sensing module are located at opposed ends of the pedal resistance force member.

2. The brake pedal assembly of claim 1 wherein the pedal force sensing module includes a deflectable strain gauge plate with a deformable strain gauge element, the strain gauge plate being deflectable and the strain gauge element

being deformable in response to the application of a force against the strain gauge plate.

3. The brake pedal assembly of claim 2 further including a bracket coupled to the pedal and extending into the pedal force sensing module and into contact with the deflectable strain gauge plate, the bracket being adapted to exert a force against the deflectable strain gauge plate in response to the movement of the pedal.

4. The brake pedal assembly of claim 1 wherein a magnet is coupled to the fixed sleeve, the pedal position sensor including a Hall Effect sensor mounted to the moveable sleeve and adapted for sensing changes in the magnetic field generated by the magnet for determining the position of the pedal in response to the movement of the Hall Effect sensor relative to the magnet.

5. A pedal resistance force member for a brake pedal and comprising:

a damper pedal resistance force module defining an interior fluid-filled cavity;

a shaft extending through the damper module and including a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force;

a spring pedal resistance force module adapted to generate a spring pedal resistance force;

a pedal force sensing module mounted to the pedal resistance force member, the pedal force sensing module including a deflectable strain gauge plate with a deformable strain gauge element, the strain gauge plate being deflectable and the strain gauge element being deformable in response to the application of a force against the strain gauge plate;

a pedal position sensor mounted to the pedal resistance force member; and

a bracket coupled to a pedal and extending into the pedal force sensing module and into contact with the deflectable strain gauge plate, the bracket being adapted to exert a force against the deflectable strain gauge plate in response to the movement of the pedal,

wherein the spring pedal resistance force module and the pedal force sensing modules are located at opposed ends of the pedal resistance force member.

6. The pedal resistance force member of claim 5 wherein a magnet is coupled to a fixed sleeve, the pedal position sensor including a Hall Effect sensor mounted to a moveable sleeve and adapted for sensing changes in the magnetic field generated by the magnet for determining the position of the pedal in response to the movement of the Hall Effect sensor relative to the magnet.

7. A pedal resistance force member for a brake pedal and comprising:

a damper pedal resistance force module defining an interior fluid-filled cavity;

a shaft extending through the damper module and including a piston mounted thereon and moveable through the fluid-filled cavity to generate a damper resistance force;

a spring pedal resistance force module adapted to generate a spring pedal resistance force;

a pedal force sensing module mounted to the pedal resistance force member, the pedal force sensing module including a deflectable strain gauge plate with a deformable strain gauge element, the strain gauge plate being deflectable and the strain gauge element being deformable in response to the application of a force against the strain gauge plate;

a pedal position sensor mounted to the pedal resistance force member; and

a bracket coupled to a pedal and extending into the pedal force sensing module and into contact with the deflectable strain gauge plate, the bracket being adapted to exert a force against the deflectable strain gauge plate in response to the movement of the pedal, 5

a pedal resistance force member including a moveable sleeve and a fixed sleeve, the moveable sleeve moving in response to the movement of the pedal, the shaft being operably coupled to the moveable sleeve and moveable in response to the movement of the moveable sleeve, the spring pedal resistance force module being coupled to the fixed sleeve and including first and second springs compressible in response to movement and contact with the shaft and the fixed sleeve respectively for generating the spring pedal resistance force. 15

8. The pedal resistance force member of claim 7 wherein the pedal force sensing module is coupled to the moveable sleeve.

9. The pedal resistance force member of claim 7 wherein a magnet is coupled to the fixed sleeve, the pedal position sensor including a Hall Effect sensor mounted to the moveable sleeve and adapted for sensing changes in the magnetic field generated by the magnet for determining the position of the pedal in response to the movement of the Hall Effect sensor relative to the magnet. 25

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